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ABSTRACT

This paper is a survey of publications on artificial neural networks published in business journals for the period ending July 1996. Its purpose is to identify and analyze trends in neural network research during that period. This paper shows which topics have been heavily researched, when these topics were researched, and how that research has changed over time. Findings indicated a total of 537 articles related to neural networks in the ABI/Inform database. Eighty-nine percent of these articles were published since 1990. A majority of these papers were classified as theoretical, closely followed by articles on applications of neural networks. Only nine percent of the articles were empirical in nature. Until 1993 there was an exponential trend in the number of articles published followed by a stagnant growth thereafter. Finance topped the list in the number of articles published followed by engineering. Among the business areas, accounting had the least number of articles with a few business areas such as insurance and human resources untouched by neural networks. (Author/AEF)

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# A SURVEY OF NEURAL NETWORK PUBLICATIONS

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*This paper is a survey of Neural Network publications published in business journals for the period ending July 1996. Its purpose is to identify and analyze trends in Neural Network research during that period. This paper shows which topics have been heavily researched, when these topics were researched, and how that research has changed over time. We found a total of 537 articles related to Neural Networks in the ABI/Inform database. Eighty nine percent of these articles were published since 1990. A majority of these papers were classified as theoretical closely followed by articles on applications of Neural Networks. Only nine percent of the articles were empirical in nature. Until 1993 there was an exponential trend in the number of articles published followed by stagnant growth thereafter. Finance topped the list in the number of articles published followed by engineering. Among the business areas, accounting had the least number of articles with a few business areas such as insurance and human resources untouched by Neural Networks.*

## INTRODUCTION

Artificial Neural Networks (NN) represent a relatively recent Artificial Intelligence (AI) technology. Biologically inspired, NN offer a new approach to solving ill-structured problems that are not easily solved using procedural solutions. Neural Networks are composed of elements that perform in a manner similar to that of the biological neuron. While the NN used in business applications are much simpler than the network of neurons found in the brain, the elements are organized in a way that may be related to the anatomy of the brain. NN have the ability to learn from experience, generalize from previous examples, and abstract characteristics from "fuzzy" data.

Neural Network research and applications have not been as widely reported as those of Expert Systems (ES), another better-known AI technology. A recent survey of operational ES in business found records of 440 expert systems in use, with most of the papers published since 1986 (Eom, 1996). ES applications can be found in manufacturing, banking and finance, retail, and various other industries.

Real interest in the field of NN as an approach to imitating human intelligence for the purpose of creating intelligent machines just began in the 1980s (Zahedi, 1993). Most of the reports on NN prior to this time were by researchers in academia, the government, and R & D laboratories (Vijayaraman & Osyk, 1994). Only in recent years have practitioners in the business world begun to report on applications of this technology. Our goal is to inform both academicians and practitioners about the trends in NN research and applications over the last ten years.

## METHODOLOGY

We searched the ABI/Inform database to identify Neural Network related publications. ABI/Inform provides abstracts for articles from over 1000 business related publications,



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including professional, academic and trade journals. Abstracts of articles have been published since 1971. We first used the key words Neural and Network to search article title, subject and abstract. This search resulted in 415 articles. Then we searched for key word Neural Network* (* is used to find other word endings) which resulted in 805 articles. We further used the definition of Neural Networks to identify the papers which were related to Neural Networks. We excluded papers which casually mentioned the word Neural Networks in their title or abstract but did not focus on Neural Networks. We finally used 537 articles for this survey. This methodology is somewhat consistent with the survey conducted by Eom and Lee (1990) on Decision Support Systems and Eom (1996) on Expert Systems. We first classified the articles identified by year and application areas. Then we classified the articles by three categories: application, descriptive, and empirical. Articles under application category focused on the use of NN for a specific application. Descriptive articles focused on descriptions of NN, its benefits and costs, how to develop NN, how to implement NN, and other theoretical focuses. Empirical articles included case studies, comparisons of NN with other traditional methods like regression and econometric models, and experimentation using NN.

## ANALYSIS

The objective of this research was to examine the development pattern of Neural Networks to date. To accomplish this task, we summarized the NN publications identified from the ABI/Inform database into area of application, year of publication, category of publication (application, descriptive, and empirical) and identified the journals that have published ten or more articles.

### Classification of Publications by Areas and Year

The abstract of each article identified as NN related publication was thoroughly examined and classified into one of the 14 categories (Table 1). Table 1 clearly indicates the upward trend in NN publications in business related areas. There were no articles listed on NN prior to 1986. Since 1986, the number of articles on NN has steadily increased. Table 1 indicates a big in NN article publications from 1992 to 1993 (more than 100% increase) and since 1993 it has leveled off (the number of articles for 1996 is for 7 months only). Only 11% of the articles on NN were published before 1990 and the remainder between 1991 and 1996. Before 1991, most of the articles published were in non-business areas. Since 1991, publications in the areas of finance, production, marketing and other business areas have steadily increased.

Among the different areas of publication, engineering and finance each accounted for over 15% of the articles and together represented more than 33% of the total number of articles reviewed. Next, were articles on production and NN software and hardware issues with each more than 9% of the total. Medicine and accounting were at the bottom with less than 2% of the total number of articles reviewed. Other business areas such as MIS and marketing had less than 5% of publications each. There were several other areas of business such as insurance, human resources, international business, and strategic management that were not addressed by NN literature.

### Classification of Publications by Category and Year

The publications were classified into three areas of focus: application, descriptive, and empirical. Application articles include description of NN applications currently in use. Descriptive articles discuss the What and How of NN technology, advantages and disadvantages, cost/benefit analysis, and implementation issues. Empirical articles include case studies, results of surveys, and articles that test NN frameworks and author's hypotheses.

Table 2 presents the breakdown of the three categories by year. Out of 537 articles reviewed, almost 50% of the articles were descriptive in nature indicating the field is still in the development stage and has not reached maturity yet. Another 41% of the publications were application oriented with only 9% of the publications falling into the empirical category. There was increase in all three categories over the last 10 years. Surprisingly, there were no publication of NN articles in the empirical category till 1991. It can be seen from this Table how research is changing over time. Yet, there is still a big gap in the empirical research of NN.

**TABLE 1**

**CLASSIFICATION BY YEAR AND AREAS**

| Area | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 | 96 | Total | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Accounting | | | | | | 1 | | 1 | 1 | 2 | 2 | 7 | 1.30 |
| Computer Hardware/Software | | | 1 | 1 | 2 | 2 | 5 | 4 | 4 | 4 | 4 | 27 | 5.02 |
| Engineering | | | 2 | 1 | 1 | 7 | 9 | 15 | 16 | 14 | 17 | 82 | 15.27 |
| Finance | | | 1 | | 1 | 6 | 12 | 22 | 23 | 25 | 9 | 99 | 18.44 |
| Forecasting | | | | | 2 | | 1 | 1 | 13 | 9 | 5 | 31 | 5.77 |
| General applications | | 1 | 2 | 3 | 1 | 5 | 3 | 7 | 12 | 4 | 4 | 42 | 7.82 |
| Medicine | | | | 1 | 1 | 1 | 1 | | | 1 | 1 | 6 | 1.12 |
| MIS | | | 1 | | 3 | 2 | 2 | 3 | 1 | 4 | 1 | 17 | 3.17 |
| Marketing | | | | | | 2 | 1 | 5 | 4 | 5 | 9 | 26 | 4.84 |
| NN Software and Hardware | 2 | | 5 | 4 | 6 | 2 | 4 | 11 | 8 | 7 | 1 | 50 | 9.31 |
| Operations | | | | | | | | | | | | | |
| Research | | | | 1 | | 2 | 2 | 5 | 15 | 11 | 5 | 41 | 7.64 |
| Production | | | 1 | 1 | 2 | 5 | 6 | 20 | 5 | 8 | 3 | 51 | 9.50 |
| Statistics | | | | | | | 3 | 10 | 2 | 3 | 2 | 20 | 3.72 |
| Others | 1 | 3 | 3 | 1 | 6 | 2 | 3 | 6 | | 11 | 2 | 38 | 7.08 |
| Total | 3 | 4 | 16 | 13 | 25 | 37 | 52 | 110 | 104 | 108 | 65 | 537 | 100 |

**TABLE 2**

**CLASSIFICATION BY YEAR AND CATEGORY**

| Year | Application | Descriptive | Empirical | Total |
|---|---|---|---|---|
| 86 | 2 | 1 | 0 | 3 |
| 87 | 1 | 3 | 0 | 4 |
| 88 | 9 | 7 | 0 | 16 |
| 89 | 4 | 9 | 0 | 13 |
| 90 | 8 | 17 | 0 | 25 |
| 91 | 13 | 22 | 2 | 37 |
| 92 | 24 | 23 | 5 | 52 |
| 93 | 47 | 54 | 9 | 110 |
| 94 | 40 | 48 | 16 | 104 |
| 95 | 50 | 47 | 11 | 108 |
| 96 | 25 | 36 | 4 | 65 |
| TOTAL | 223 | 267 | 47 | 537 |
| PERCENTAGE | 41.53 | 49.72 | 8.75 | 100 |

**Classification of Publications by Category and Areas**

The articles were also classified by category and areas to see which areas have more NN application related articles (Table 3). Finance (67%) had the maximum number of application related articles followed by engineering (50%). Whereas engineering had the highest number of descriptive articles (49%), followed by Production (60%).

The operations research and statistics areas had the maximum number of articles in the empirical category. Finance, engineering, medicine, and NN software/hardware areas had more articles published in the application category than the descriptive category. Only statistics had more articles under empirical category. Table 3 also indicates that there are more application articles published among the business areas than descriptive articles and there is a serious lack of empirical research.

**TABLE 3**

**CLASSIFICATION BY AREAS AND CATEGORY**

| | Application | Descriptive | Empirical | Total |
|---|---|---|---|---|
| Accounting | 5 | 1 | 1 | 7 |
| Computer | 12 | 14 | 1 | 27 |
| Engineering | 41 | 40 | 1 | 82 |
| Finance | 67 | 23 | 9 | 99 |
| Forecasting | 7 | 18 | 6 | 31 |
| General | 15 | 24 | 3 | 42 |
| Medicine | 4 | 2 | 0 | 6 |
| MIS | 8 | 9 | 0 | 17 |
| Marketing | 9 | 17 | 0 | 26 |
| NN Software/Hardware Operations | 8 | 21 | 12 | 41 |
| Research Production | 17 | 31 | 3 | 51 |
| Statistics | 2 | 7 | 11 | 20 |
| Others | 0 | 38 | 0 | 38 |
| TOTAL | 223 | 267 | 47 | 537 |

Table 4 identifies journals that have published ten or more NN articles. There were eleven journals which published 37% of the total articles identified in this survey. Computers and Industrial Engineering had the highest number of articles published (8.38%) followed by Microprocessing & Microprogramming (6%). There were more than 100 journals and magazines that published the NN articles from 1986 to 1996. Many of the articles reviewed were published in trade journals and magazines compared to scholarly journals.

## IMPLICATIONS OF NEURAL NETWORKS FOR BUSINESS

Many challenges continue to exist with respect to the design, implementation, and evaluation of neural networks in business applications. A number of decisions must be made regarding the structure of the system. One must determine the appropriate software to use, the architecture of the network, the method of learning, etc. When implementing neural networks, a number of questions must be addressed. How will the neural network application be integrated with existing systems? What type of interface is needed? Also, how will organizations evaluate the success of neural networks? More research must be done on the criteria for measuring machine intelligence. How can one measure reliability ? How can one determine the cost/benefit of neural network applications? What resources will be necessary for organizations to support and manage the development, implementation, and evaluation of new technologies?

**TABLE 4**

**JOURNALS WITH 10 OR MORE ARTICLES ON NN**

| Journals | Number of Articles |
|---|---|
| Credit Card Management | 10 |
| Computers in Industry | 11 |
| Computers and Industrial Engineering | 45 |
| Computer World | 14 |
| Computers and Operations Research | 18 |
| Decision Support Systems | 14 |
| European Journal of Operations Research | 13 |
| FutureS | 22 |
| IEEE | 10 |
| Manufacturing Systems | 10 |
| Microprocessing & Microprogramming | 31 |
| **Total** | **198** |

As more neural networks are developed and implemented, more information will be available to answer the above questions. It is clear from our search that neural network applications are on the increase in a number of functional areas, including engineering, finance, and production/ operations management. More published information on the successes and failures of these applications, the challenges faced, and the solutions found, will continue to be very important to those practitioners interested in developing applications of their own.

## IMPLICATIONS FOR FUTURE RESEARCH

Neural networks and neural network

applications will continue to be important to academicians on two fronts: research and teaching. As noted earlier, our search found that a significant number of neural network articles appeared in trade journals and magazines. From a research perspective, many opportunities exist to "fill in the gaps" in the academic literature. Empirical articles represented less than ten percent of the total articles published. For example, in the finance area, with a total of 99 articles, only nine of these were empirical in nature. Clearly, many opportunities exist to add to the body of knowledge on these topics.

A limitation of this study is that it only surveyed articles published in the ABI-INFORM database. While this database did provide a comprehensive listing of articles published in business-related periodicals, a number of sources were excluded. Many opportunities exist to expand on this study. To develop a comprehensive bibliography of neural network articles, a number of other sources should be utilized. Comprehensive databases exist in the computer science field, the medical field, and in other areas. These databases should be utilized in future research. In addition, articles published in many periodicals typically suffer from a "time lag" effect from when the information was researched to when the article was ultimately published. A comprehensive survey should include other sources including dissertation abstracts and relevant conference proceedings. These sources would undoubtedly contain more up-to-date and state-of-the-art material.

From a pedagogical point of view, articles that investigate the trends in the development and implementation of new technologies such as neural networks will continue to be important. Comprehensive lists of resources will also be very important to educators. Academicians are continually trying to bridge the gap between theory and practice. Textbooks that report on cutting edge technologies are soon outdated. Instructors frequently must rely on other outside reading assignments. Because of the dynamic nature of the field, it is important that educators remain aware of the current developments in the field, including current trends where applications are being implemented, the problems with implementation, etc.

## CONCLUSIONS

This paper provided a survey of neural network publications in business journals through July 1996. A number of conclusions may be drawn from the results of this survey. First, there has been a significant increase in the number of neural network publications in recent years, presumably reflecting an increase in interest in their development and implementation. Second, publications in certain areas (such as engineering, finance and production/operations management) have exceeded the publications in many other areas. Third, the gaps in the literature indicate that many opportunities exist to report on additional research efforts in the development and application of neural networks. Finally, many opportunities appear to exist for collaborative efforts between academicians interested in theory and practitioners interested in implementation.

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